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Econometric perspective of the energy consumption and economic growth relation in European Union

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ABSTRACT

This paper's aim is to examine the relationship between energy consumption by fuel end economic growth in a comparative analysis for Spain, Romania and European Union. Applying a methodology in three steps on data for the 1990–2010 period, long-run and short-run relationships are revealed. On long-run, the energy consumption with total petroleum products source yields evidence of linkage with economic growth (proxied by Gross Domestic Product per capita in constant prices) for both two states and European Union. Furthermore, on short run only two relationships were emphasized both sustaining the growth hypothesis. So, in Romania, renewable energy consumption influences on short run the economic performance of activities; the relation is unidirectional and is not valid in the other direction, meaning that economic growth does not cause renewable energy consumption. In Spain, energy consumption with source natural gas causes economic growth on short-run, and the relation is valid just in this direction. The findings of this study help understanding the energy-growth nexus which stands behind all energy policies.

Contents

1. Introduction

From the beginning of the Industrial Revolution, the energy was exploited in an exponential way, fact that increased its importance over time. Nowadays, the energy consumption per capita is one of the indicators that describe the economic development of a country. It is well known that the spread of energy consumption is still unequal. There are developed or developing countries "absorbing" a great amount of energy and also countries less developed, that are only consuming a thin slice of the world's energy pie (the case of African countries). Therefore, there is a well shaped relationship between economic growth and energy consumption. They are both evolving in the same direction, but not in the same rhythm. The relationship between them is not constant, but it changes with time and driven by the national differences.

When speaking about the economic development of country, we refer to growth ratio of energy consumption superior of those of gross domestic product. This situation appears in the early stages of development and it is then followed by stages of growth ratio of energy consumption inferior to those of gross domestic product. These characteristics are due to structural changes in each economy and to technical and technological progress.

In the same time, the energetic consumption—economic growth relationship also brings into attention the differences in equipments used in the energy field among countries. There are

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also differences in the use of energy, meaning the sectors for which the energy is intensively used. In general, the industry and transport are energy intensive, while agriculture for example, is not so hungry for energy.

In the future, is expected that the demand for energy to continue its upward trend. Another expected phenomenon, which started a long time ago and continues today, is the substitution among energy forms. Now the renewable energy is expected to take the lead in the race with fossil fuels. There are various reasons sustaining this substitution [1–3] and without getting into too much detail, we present them below

- Renewable energy fit in the category of resources with respect to the environment, having a low impact in time and space.
- Renewable energy imply, if rationally used, long-term availability, compared to fossil fuels.
- The renewable energy potential is huge and it represents one of the safest ways of handling the increasing energy demand, without affecting the balance of an economic development; this is also known as the security of energy supply.
- The exhaustible character of fossil fuels. The earth's reserves of nonrenewable energy are assumed to run out sooner or later.
- Renewable energies are related to regional development and social progress, as they could be found everywhere and exploited also in areas less developed, with a greater level of poverty.

So, in order to highlight the importance of renewable energy, we study its corresponding relation with Gross Domestic Product (GDP), as a representative for economic growth. There are three possible directions of this relation [4]

- Starting from energy consumption to economic growth, which states the fact, that energy is an important engine for the economy and sustains the so-called growth hypothesis; this case makes the economy energy dependent [5], so each change in energy consumption is reflected in GDP.
- Starting from economic growth to energy consumption, which means that a country does not depend on the energy consumption in order to obtain economic growth, but contrary, when achieving a level of development, it appears a greater energy demand; this is the conservation hypothesis. It represents the optimal situation for implementing, without negative effects, energy conservation policies in a society.
- A bidirectional relation between the two of them, which can also be called as a "feedback". Energy consumption and economic growth influence each other, with implications on energy policies. These should focus on energy efficiency measures, reduction of energy consumption from traditional sources, usage of renewable energy instead of conventional energy, all contributing to decreasing greenhouse gas emissions.

Obviously, there can be mentioned a fourth situation, the one of no relation established between these two variables, also called the neutrality hypothesis.

We include in the analysis also the energy consumption from coal, oil and natural gas, as these are a considerable part of the energy supply in most countries. In the same time, knowing what type of energy follows the growth hypothesis (which is the second one mentioned above), makes it easy evaluating the possibilities of substitution with renewable energy. As far as we are concerned, there are no studies made that separate the energy consumption by energy source. This work is related to a previous one, where we tried to analyze the same relationship but just for one country. The need of including another country in the study and comparing the results with the general case of European Union (as Romania and Spain are both member states of European Union) appeared as a prerequisite to the validity of the conclusions.

2. Literature review

In the context of global economy, researchers around the world have tried to find the absolute truth about factors with impact on economic growth. Over the years, key concepts were analyzed with the aim to explain their influence in the variability of growth. Energy is a relatively new factor seen as a driving force of economic growth that was not included in the growth models, as Stern [6] explains it. It is quite true that neither Solow's growth model (where technological progress is considered a factor of growth), nor AK models (where higher savings increase the economy's growth rate) or Schumpeterian growth models (capital accumulation and innovation are influencing the growth rate) include resources of energy. Others, like Romer [7] or Grossman and Helpman [8] insist that research and development represents a base for economic growth.

Nicolae Georgescu Roegen is considered to be the one of the first scientists that combined the concept of economic growth with the one of natural environment. In its well-known work published in 1971, called The Entropy Law and Economic Process, he demonstrates that in an economic process, material degradation occurs. This automatically implies that the used material could never be used in other economic activities [9]. So, a remark to the neoclassical economical model, made by Georgescu-Roegen is that of not taking into account the principles of energy and material degradation. Professor Shahid [10] is a proponent of this theory and constructs its own on this base. He deals with a variety of ideas, among them: an economy that recognizes the importance of the energy, which brings important changes in the capital and labor functions and has key contributions to economic growth. Another interpretation to estimate and forecast the rate of growth with focus on the Spanish economy, this time, is the one of Cuevas and Quilis [11]. The authors include energy consumption in the model, in order to capture the evolution of economic activity.

We do believe that economic growth represents a basic frame for sustainable development as well as for economic development. It points out to a society's capacity to enrich itself, an important aspect when it comes to raising all people's wellbeing and implicitly for sustainability. So on and so forth, sustainable development cannot establish its own objectives to accomplish and rules to follow, without taking into account those of each economic system. We therefore, try to refer to them, but without further details; so the objectives of an economic system are: growth in equilibrium, growth of economy's competitiveness, increasing the capacity of generating employment; distributing richness among people, regions and generations [12].

So, these three elements, energy consumption, economic growth and sustainable development, they all connect to each other. We should not forget that sustainable development is built on three pillars, social, economic and environment, pillars that should have a solid base, such as a region, country or even city [13].

In the last decades, an increased interest to study the relation economic growth-energy consumption has been shown [14]. Various studies released expected or unexpected results in their trial to establish the role of energy in economic development. According to the methodologies used, the period of study and the countries included in the analyses made, macroeconomists and all interested researchers provided insights of the relevant coordination of energy consumption and economic growth. Concluding

that "macroeconomic energy modeling is vital for every nation"; Suganthi and Samuel [15] recently reviewed all existing models used in analyzing this great issue of our times, offering an important work and starting point for other future studies, inspiring in choosing the proper type of model to analyze.

Since the first studies in this regard, evidence was found to sustain the different types of this relation. We consider it more appropriate to relate to studies that are closest to the present work's analysis.

Proofs that energy consumption affects economic growth can be found at Paul and Bhattacharya [16] which demonstrated the unidirectional causal relation for India. Another unidirectional relation but exerted by economic growth on energy use is revealed by Aziz [17] for Malaysia. The author begins the analysis with energy consumption as a dependent variable and uses three econometric procedures (testing stationarity, cointegration and causality) which reveal the importance of energy conservation for Malaysia.

Weak evidence about the long-run and short-run relationships between energy consumption and economic growth was argued for countries like Albania, Bulgaria, Romania and Hungary [18]. In countries from Europe and Central Asia, energy strongly affects economic growth as shown in a study that uses a growth framework [19]. The same study reveals that the energy variable is found with no impact on economic growth for regions in Sub-Saharan and Caribbean. On one hand, for Sub-Saharan African countries, researchers indicate that the energy sources should be diversified and accompanied by energy efficiency measures [20]. On the other hand, for Caribbean countries issues regarding the use of new technologies for energy production and distribution are suggested [21]. For South Asian countries like Nepal, India and Pakistan, economic growth Granger causes electricity consumption, supporting the relation on short-run between the two of them [22]. In their panel data approach, the authors also examine and estimate the long-run relationship for Bangladesh, India, Iran and Nepal, concluding that Asian economy in the observed countries is strongly driven by electricity consumption over time. Another study (in Botswana) using the electricity consumption as a proxy for energy in relation to economic growth [23] goes further with the investigation and includes capital formation in the system, in order to capture its impact to the national economy.

A feedback hypothesis (a causality running in both directions in long-run) is discovered for countries like Portugal, Italy [24], Greece, Spain and Turkey [25]. Carrying out their analysis in a non-linear context, Dergiades, Martinopoulos and Tsoulfidis discover a unidirectional linkage running from energy to economic growth in Greece [26]. The nexus energy-growth was also in the attention of Soytas and Sari [27], describing in their work that economic growth can lead to increased energy consumption in Italy and Korea and the other way round in Turkey, France, Germany and Japan. Concerns regarding the implications for Turkey are widely expressed in a large number of studies, as Turkey represents a strategic place in the route of oil and natural gas [28–30,31]. Erdal et al. and Bowden and Payne [31,32,33] focused on US data for 57 years, accepting the growth hypothesis between renewable and non-renewable energy consumption and real GDP.

Imran and Mashkoor Siddiqui [34] considered a panel analysis with capital stock and labor input, for Bangladesh, India and Pakistan. Their findings indicate that not only the growth hypothesis is accepted, but also the conservation one. Another panel approach is the one of Noor and Siddiqi [35] that includes countries from South Asia, for which a unidirectional causality is found from economic growth to energetic consumption in the short-run. The analyses conducted using panel data have the advantage of making use of a lot of observations, which are various variables in time and space. For instance, Joyeux and Ripple [36] handled four variables (GDP, Total Electricity, Residential Electricity and Total Energy) described for 30 OECD countries and 26 non-OECD for the 1973–2007 period. This is a comprehensive study which not only seeks to determine the causality on short run and long run but to highlight various techniques' contribution and implications to the analysis. Their conclusion is that mostly, the relationship heads from income to energy consumption, with some differences if comparing OECD and non-OECD countries.

Authors like Lau et al. [37] also use panel approach, in order to perform their investigation on 17 Asian countries. The novelty lies in the method of establishing cointegration (Pedroni test and Kao test) and estimating the coefficients for the cointegrating relationship: Fully Modified Ordinary Least Squares (FMOLS). A long-run equilibrium is revealed between energy consumption and gross domestic product, with a positive sign, meaning increases in GDP may influence increases in energy use. Moreover, Ciarreta and Zarraga [38] conducted their causality analysis on panel data for 12 European countries using the same method of FMOLS. Their findings suggest that changes in energy consumption induce changes of different intensities in GDP on long-run for each country studied.

Going further, there are authors focused on the impact of renewable energies on economic growth and CO_2 emissions [39–41]. It is known that CO_2 emissions are in fact a result of fossil fuels combustion and that puts the energy sector in a situation of being responsible for the climate change. This involves cost-effective policies with the aim to reduce the environmental problems [42,43]. There are authors describing relations of energy demand and CO_2 emissions or energy demand and population growth [44]. For instance, several authors [45,46] refer to the interplays among economy, energy and environment arguing the importance of realizing economic growth while reducing greenhouse gases emissions and controlling traditional energy consumption. As revealed in a recent study, energy consumption Granger causes CO_2 emissions, which cause economic growth in the short-run and long-run [47].

Hannesson [48] examined the relationship between the growth in energy use and the growth of gross domestic product, to see if it varies with the richness of a country. For richer countries is valid the next result: the energy growth is less sensitive to the GDP growth. Another interesting approach is the one of Constantini and Martini [49] which take into account developed and developing countries and study the most wanted relation both at entire economy level and at sectoral level (industry, service, transport and residential). There are also authors who prefer using instead of energy consumption or electricity consumption, one source of energy, such as natural gas [50] or coal consumption [51] in order to find significant relationships. Last but not least, there are works [52–54] providing evidence for decoupling economic growth from energy consumption.

Some of the studies referred to till now, are centralized in Table 1. To these ones are added a few mentioned in Belke et al. [5] in order to reveal the first and the latest studies that are contributing to the energy consumption-economic growth debate. Findings like Economic Growth $\approx$ Energy consumption suggest the neutrality hypothesis, while Economic Growth $\Rightarrow$ Energy consumption suggests the growth hypothesis, Economic Growth $\Leftarrow$ Energy consumption: the conservation hypothesis and Economic Growth $\Leftrightarrow$ Energy consumption: the feedback hypothesis.

The most part of the literature has provided so far a great amount of results concerning the role of energy [55] in economic growth and their relation on short run and long run. Countries with different development levels and policies, with various institutional

Table 1
Studies on the relationship energy consumption-economic growth with main findings.
Source: authors after Belke et al. [5].

Authors of the study	Year	Findings	Studied country
Kraft and Kraft	1978	Economic growth ⇒ Energy consumption	USA
Yu and Choi	1985	Economic growth ⇒ Energy consumption	South Korea
		Economic growth ⇐ Energy consumption	Philippines
Erol and Yu	1987	Economic growth ≈ Energy consumption	USA
Masih and Masih	1996	Economic growth ≈ Energy consumption	Malaysia
		Economic growth ⇒ Energy consumption	India
		Economic growth ⇐ Energy consumption	Indonesia
		Economic growth ⇔ Energy consumption	Pakistan
Glasure and Lee	1998	Economic growth ⇔ Energy consumption	South Korea
		Economic growth ⇔ Energy consumption	Singapore
Asafu-Adjaye	2000	Economic growth ⇐ Energy consumption	India and Indonesia
		Economic growth ⇔ Energy consumption	Thailand&Philippines
Hondroyiannis et al.	2002	Economic growth ⇔ energy consumption	Greece
Soytas and Sari	2003	Economic growth ⇒ Energy consumption	Italy and Korea
		Economic growth ⇐ Energy consumption	Turkey, France, Germany and Japan
Paul and Bhattacharya	2004	Economic growth ⇐ Energy consumption	India
Lee	2005	Economic growth ⇐ Energy consumption	18 developing nations
Francis, Moseley and Iyare	2007	Economic growth ⇐ Energy consumption	Caribbean countries
Bowden and Payne	2009	Economic growth ⇐ Energy consumption	US
Sharma	2010	Economic growth ⇐ Energy consumption	Europe and Central Asia
Noor and Siddiqi	2010	Economic growth ⇒ Energy consumption	South Africa
Aziz	2011	Economic growth ⇒ Energy consumption	Malaysia
Magazzino	2011	Economic growth ⇔ Energy consumption	Portugal and Italy
Hossain and Saeki	2011	Economic growth ⇒ Energy consumption	Nepal, India and Pakistan
Dergiades, Martinipoulos and Tsoulfidis	2011	Economic growth ⇐ Energy consumption	Greece
Fuinhas and Marques	2012	Economic growth ⇔ Energy consumption	Greece, Spain and Turkey

and structural frameworks, were the main base for these studies. Even though, sometimes conflicting results were obtained, this is due to estimation techniques, the period of the analysis, the type and number of variables included, the tests applied.

3. Data and methodology

With the aim to study the relationship in the short-run and long-run between energy consumption by source and economic growth, we collected time series data for the period 1990–2010 for three entities: Spain and Romania (as individual countries) and European Union (EU) (as an average of all European countries); this choice was made for the simple reason of comparing the results obtained for Spain and Romania, member states of EU, with the ones seen as an average for all European Union's states. On all time series used, changes were effectuated to obtain the values per capita. So, in order to use the data, the next time series were modified

- Population, for Romania and Spain [56] and for European Union with 27 member states [57]. The values for 2009 and 2010 are provisional just for EU-27 [58];
- Gross inland energy consumption, by fuel [59]: Natural gas, Total petroleum products, Solid fuels, Renewable energies 1000 t of oil equivalent, all expressed in 1000 t of oil equivalent;
- Gross Domestic Product constant 2000 US dollars [60].

Gross inland energy consumption, as Eurostat defines it is calculated as follows: primary production plus recovered products plus total imports plus variations of stocks without total exports and bunkers. It corresponds to the addition of final consumption, distribution losses, transformation losses and statistical differences. Total petroleum products refer to liquefied petroleum gases—LPG, refinery gas, motor spirit, kerosenes, gasoline type jet fuels, kerosene type jet fuels, naphtha, gas/diesel oil, residual fuel oil, white spirit, lubricants, bitumen, petroleum coke and other petroleum products. Last but not least, the types of energy included in renewable energy refer to biomass, hydropower, geothermal energy, wind and solar

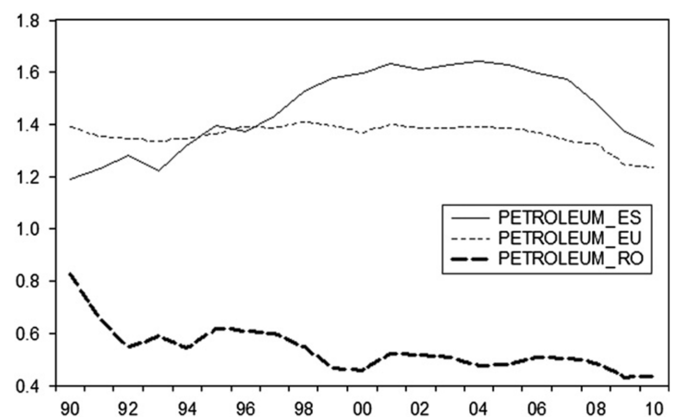

Fig. 1. The evolution of energy consumption (petroleum).

energy. EU-27 includes: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

The level of energy consumption with source total petroleum products, for Romania, in the period considered, is inferior to the level of the same indicator in Spain and EU-27 (Fig. 1).

In Romania, the energy consumption with source natural gas (Fig. 2), was till 1996 superior to the one in Spain and EU-27, even if it had a constant declining. In the same time the consumption mentioned, continued to grow in Spain and EU-27, reaching since 2005 (for Spain) and 1996 (for EU-27) important growths.

In Fig. 3, one can see that solid fuels as a resource of energy, were quite abandoned in EU-27 along time and in Romania and Spain also, beginning with 2007, when they had a peak and the start for the decay.

Renewable sources of energy (Fig. 4) are gaining by far the competition of most wanted sources of energy in this era. It seems that in 1997, in Romania, the consumption of energy from

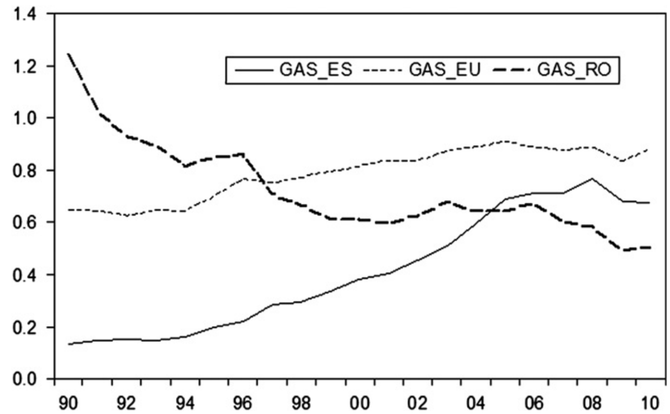

Fig. 2. The evolution of energy consumption (natural gas).

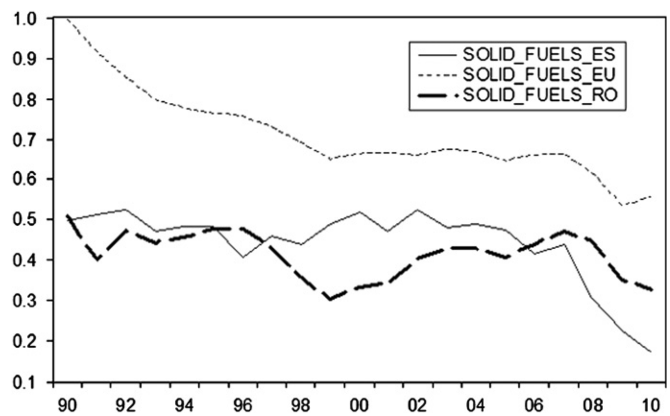

Fig. 3. The evolution of energy consumption (solid fuels).

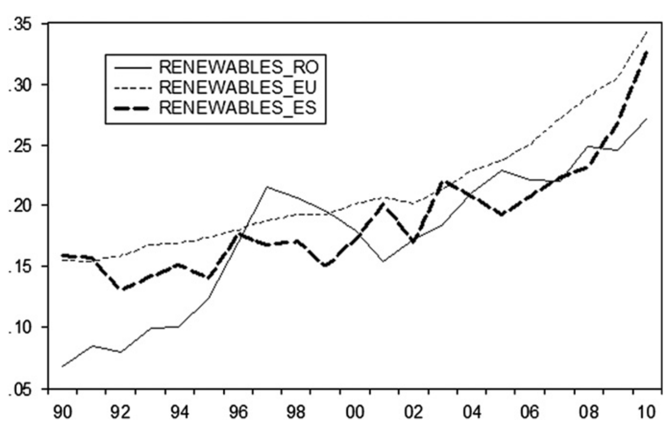

Fig. 4. The evolution of energy consumption (renewables).

renewable sources was greater than in Spain and comparative with the average level in European Union. Despite the availability of renewable energy sources in EU, they still have a reduced contribution to the overall gross electricity generation [61].

As for the evolution of GDP per capita, Fig. 5 reveals that Spain is a "follower" of the EU-27, as it copy's perfectly its trend.

The authors worked with the Eviews 7 software, where the time series have been named after the source of the energy, for instance Petroleum, Solid_fuels, Renewables, Gas. The Gross Domestic Product in constant 2000 US dollars per capita was named simply GDP.

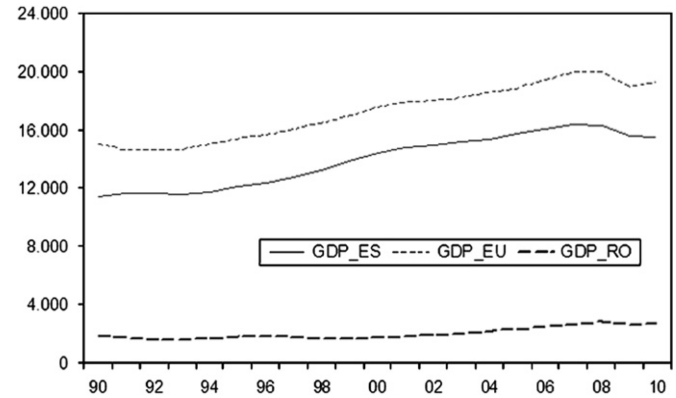

Fig. 5. The evolution of GDP per capita.

The methodology used is one in three steps

1. Testing stationarity of the series;
2. Testing cointegration for the stationary series;
3. Testing causality for the cointegrated series.

Following the basic idea of the methodology in three steps, but using the Hsiao version of Granger causality test and FPE criterion, Aqeel and Butt [62] demonstrated that economic growth causes energy consumption in Pakistan. Lorde, Waithe and Francis begin their analysis with the logarithmic time derivative of the aggregate production function

$$Y = AK^{\alpha}L^{\beta}E^{\gamma} \tag{1}$$

They obtain the next two cointegrating vectors which highlight the importance of energy consumption to economic growth, the first one including total electricity consumption, and the second one including non-residential electricity consumption [63]

$$LY_t = 0.712 \times LK_t + 0.133 \times TECH + 0.582 \times LTC \tag{2}$$

$$LY_t = 0.576 \times LK_t + 0.217 \times TECH + 0.584 \times LNRC \tag{3}$$

Taking into account exports as an important determinant for both economic growth and electricity consumption in Brazil, Sami and Makun provide findings suggesting exports influence real income in the long-run [64]. Using ARDL approach, they obtain the following equation with long-run estimated coefficients

$$\ln Y_t = 6.1496 + 0.27534 \times \ln E_t + 0.25969 \times \ln X_t \tag{4}$$

The coefficients can be read as elasticities and their significance is the following: if energy consumption increases by 1%, economic growth increases with almost 0.27% and if exports are increasing with 1%, economic growth is increasing with 0.25%.

Each step in the methodology is well related with the next one that follows. Let's say that we test for stationarity and we find out that our series are nonstationary. We cannot work with a nonstationary series and move forward to the co-integration, because if there is a shock to the series, it will not absorb itself over time and will be permanent [65]. Stationary processes are described by mean and variance constant in time and the value of covariance between two periods only depends on the lag between the periods [66]. So, changes to the series should be made in order to move to the next step of co-integration. As the main sources for nonstationary series are trend and breaks in the series, there are appropriate two ways of making variables stationary [67]:

- Detrending, by including a trend variable in the regression, or by extracting trend. In this way, the influence of trend on variables can be removed; for instance, if such method is

applied, the estimated coefficients from a regression will represent the net influence of independent variables on dependent one. Another important aspect that should be reminded when choosing this method is that of the existence of a deterministic trend.

- For the case of a stochastic trend, the nonstationary series can change to stationary ones if differencing is applied. For this reason, the series will be called difference stationary process or DSP.

For our case, the variables we use are supposed to be all nonstationary, for the single reason of stochastic trend existence. Anyway, a test for verifying stationarity should be done. We focused on two simple tests in order to achieve the stationarity. The first one is based on the *autocorrelation function* ACF and the graphical representation of the correlogram for certain lags [68]. The second one is called *the unit root test* of stationarity and in EViews can be made through Augmented Dickey Fuller test or ADF test [69]. To apply the test, the next equation should be estimated

$$Y_t = Y_{t-1} + u_t \tag{5}$$

where u_t is the error term with mean 0, constant variance σ^2 and nonautocorrelated, definitely called white noise. If the coefficient of Y_{t-1} is 1, than Y_t has a unit root, meaning it is nonstationary. The null hypothesis of the ADF test is the existence of nonstationarity or of a unit root.

There is a great possibility of obtaining nonstationary series. In this case we have to retest but on the first-level differences, calculated by the first difference operator, Δ_{Yt}:

$$\Delta_{Yt} = Y_t - Y_{t-1} \tag{6}$$

Supposing the first difference of the series is stationary, than the original series is called integrated of order 1, noted as I(1). This also means that the series has become stationary after the first difference.

If the series remain still nonstationary, we apply the second-level differences, which will transform the original series in one integrated two times or I(2). In general, if the series is d times differenced, than it will be called integrated of order d and noted I(d).

The second step is testing co-integration [70], with the aim of discovering a possible equilibrium in the long-run relation of two variables. We can test the co-integration if the series are integrated of the same order. The basic idea consists of estimating the regression between two variables, retaining the series of residuals and using the ADF test. For this test, the maximum number of lags is needed, so the calculus formula for maximum lags is the one of Schwert mentioned in Zivot [71]

$$\max \mathit{Lag\ Length} = [12 \times (T/100)^{1/4}] \tag{7}$$

where T is the number of observations. [m] denotes the integer part of m. The formula for the first lag length is [72]

$$\min \mathit{Lag\ Length} = [4 \times (T/100)^{1/4}] \tag{8}$$

By applying the formulas, it seems that the maximum lag length should be 8 and the minimum 2.

Co-integration also refers to the situation of a linear combination of the series that could be stationary, even though the series themselves are nonstationary. The combination should be integrated of a smaller order than the series alone [73].

Finally, after performing the test of long-run relationship between variables, the causality test could also be performed in order to validate a short-run relationship and its direction. The Granger test is used. This is a test based on the idea of using past values of a variable in order to predict the values of the other variable [74]. As we are working with annual time series, we need a lag of one for running this test with a double hypothesis: if A and B are two time series, than the hypothesis tested are "A does not Granger cause B" and "B does not Granger cause A". The decision rule of the test is based on the probability and the 5% level of confidence [75].

4. Results

By studying the autocorrelation function of each series, the results are the ones expected: all series for all three representatives, Spain, Romania and European Union, are non-stationary. The ACF representation, meaning the correlograms, are all shaped with a decreasing tendency, due to the values of AC, which dies off geometrically with increasing lag.

Going further and applying ADF test, we find out the order of integration of the series. The results are the ones presented in Table 2.

So, almost all series have become stationary after the first differencing. There are also a few becoming stationary after the second differencing. This is an important aspect to know for the next step of establishing co-integration. For EU-27, GDP per capita is integrated of order 2. It will represent the dependent variable in the regression equation for finding long-run relationship with one of the energy consumption's independent variable. Also I(2) are energy consumption with source total petroleum products and renewables. So, the existence of two long run relations can be tested. For Romania, all series excepting the one of energy consumption from solid fuels source, are integrated of the same order, which makes possible the co-integration testing. For Spain, the test can be run for GDP per capita against energy consumption with source: natural gas and petroleum products.

Residuals from each regression equation were kept and ADF test was applied. The null hypothesis of the test changed into the one of no co-integration. The decision rule was the following: the value of the ADF test is compared with the one for 95% level of confidence. If it is inferior to the critical value than we reject the null hypothesis. In all cases, with no exception, the null hypothesis of nonco-integration was rejected, which means that each series of residuals is integrated of order 0, lower than that of the variables in the regressions.

The regression equations of the stationary series are presented below. The notation d(GDP,1), for instance represents the first difference of the GDP series, which is a stationary one. For European Union the regressions are

$$d(GDP,2) = -25.0237 + 30493.689 \times d(RENEWABLES,2) \tag{9}$$

$$d(GDP,2) = 28.284 + 7379.324 \times d(Petroleum,2) \tag{10}$$

For Romania, the regression equations for testing the co-integration of the series, are

$$d(GDP,1) = 90.932 + 1457.563 \times d(Gas,1) \tag{11}$$

$$d(GDP,1) = 68.139 + 1573.363 \times d(Petroleum,1) \tag{12}$$

$$d(GDP,1) = 30.122 + 678.9015 \times d(RENEWABLES,1) \tag{13}$$

Table 2
The integration order of each series.
Source: authors' calculation in EViews.

	GDP	Gas	Solid_fuels	Petroleum	Renewables
EU-27	I(2)	I(1)	I(1)	I(2)	I(2)
Romania	I(1)	I(1)	I(2)	I(1)	I(1)
Spain	I(2)	I(2)	I(1)	I(2)	I(1)

Table 3
Results of applying Granger test (EU-27).
Source: authors' calculation.

Nr. crt.	Null hypothesis of the test	F-statistic	Probability
1	*d*(*Petroleum*,2) does not Granger cause *d*(*GDP*,2)	2.87857	0.1108
2	*d*(*GDP*,2) does not Granger cause *d*(*Petroleum*,2)	0.86862	0.3661
3	*d*(*Renewables*,2) does not Granger cause *d*(*GDP*,2)	0.0009	0.9765
4	*d*(*GDP*,2) does not Granger cause *d*(*Renewables*,2)	1.48026	0.2425

Table 4
Results after applying granger test (Romania).
Source: authors' calculation.

Nr. crt.	Null hypothesis of the test	F-statistic	Probability
1	*d*(*Petroleum*,1) does not Granger cause *d*(*GDP,1*)	0.96976	0.3394
2	*d*(*GDP*,1) does not Granger cause *d*(*Petroleum*,1)	0.38208	0.5452
3	*d*(*Renewables*,1) does not Granger cause *d*(*GDP*,1)	6.00919	0.0261
4	*d*(*GDP*,1) does not Granger cause *d*(*Renewables*,1)	0.44432	0.5145
5	*d*(*Gas*,1) does not Granger cause *d*(*GDP*,1)	1.54261	0.2321
6	*d*(*GDP*,1) does not Granger cause *d*(*Gas*,1)	0.0241	0.8882

Table 5
Results after applying Granger test (Spain).Source: authors' calculation.

Nr. crt.	Null hypothesis of the test	F-statistic	Probability
1	*d*(*Petroleum*,2) does not Granger cause *d*(*GDP*,2)	0.01972	0.8902
2	*d*(*GDP*,2) does not Granger cause *d*(*Petroleum*,2)	0.08011	0.7810
3	*d*(*Gas*,2) does not Granger cause *d*(*GDP*,2)	4.70796	0.0465
4	*d*(*GDP*,2) does not Granger cause *d*(*Gas*,2)	0.96988	0.3403

Last, but not least, the regression equations for Spain that help testing for co-integration, are

$$d(GDP,2) = -14.9617 + 2833.369 \times d(Gas,2) \tag{14}$$

$$d(GDP,2) = -4.375 + 2538.4034 \times d(Petroleum,2) \tag{15}$$

The correlation coefficient R^2 remains inferior to the Durbin Watson value for each regression estimated, fact that removes any doubt of spurious regression.

Next, to find out if short-run relationships are available, the Granger test was used for stationary variables, integrated of the same order. The results for European Unions 27 countries are presented in Table 3.

The results after applying Granger test for Romania and Spain are presented in Table 4 and in Table 5. The decision rule used is the one of Akan et al. [76]: the null hypothesis is rejected if probability associated to F-statistic is ≤ 0.05 and the null hypothesis is accepted if the associated probability of F statistic is > 0.05.

5. Discussion

Applying the three steps methodology, important findings where revealed. Limited by the order of integration, just a few relations could be tested for long-run relationship. The good news is that all appeared to be linear combination, integrated of a lower order, which means that the relation that we were searching for, is indeed a true one.

In European Union, between economic growth and energy consumption with source renewables and petroleum products, long run equilibrium is established. As a matter of fact, energy consumption with source petroleum products is the one which appears in all three cases, of Spain, Romania and EU-27. It is understandable, when thinking that oil is the main fuel for transport, an energy intensive sector. Simultaneously, we have seen the evolution of energy consumption with renewable energy source; they strengthen their position with every coming year and for reasons previously posted. Romania follows the tendency observed in European Union, that of the great influence of renewable energy consumption on economic performance.

Most long run relationships were found for Romania, where natural gas, petroleum products and renewable energy are the main sources for energy consumption that affects GDP. As can be seen from the regression equations, there is a positive association between energy consumption and economic growth, which means that any positive change in energy will have a positive impact on GDP.

In Spain, the energy consumption from gas and petroleum products sources is likely to stimulate economic growth on long-run. Renewables were also expected to have a statistically significant effect on economic growth, taking into account that Spain, unlike Romania, has a production of renewables two times higher. As the same country energy statistics show [77], for instance in 2007, the renewable energy sources share in gross inland consumption is 7.01% in Spain and 11.86% in Romania. So even if Spain produces more renewable energy, its share in consumption is smaller, compared with Romania.

As for the short-run relationships, things turned in an unexpected way, because as the results are showing, only two such relations are valid. The null hypothesis of Granger test could be rejected in two cases: the one of energy consumption with source renewable forms of energy "not Granger causing" GDP per capita (for Romania) and the second one of energy consumption with source natural gas "not Granger causing" GDP per capita (for Spain). If we think about it, for EU-27 is quite simple why such a relationship does not occur. Countries differ in many respects, so a short-run relationship is difficult to be obtained when there are so many things to consider.

Therefore, renewable energy forms have a positive effect on both long run and short run on the economic growth of Romania. In short run, they sustain the growth hypothesis, so Romania does need renewable energy to stimulate economic growth. In Spain, the growth hypothesis is also valid but with a causal relation starting from energy consumption with source natural gas to GDP per capita. If we consider the evolution of this consumption for the period 1990–2010, we see that it had an increasing tendency, compared with the other energy consumptions which had alternating courses.

The limitations of this study gather around some issues regarding

(a) The period 1990–2010 chosen for the availability of data; for instance if a larger period is considered, it is quite possible to obtain different results.
(b) The methodology used by qualified institutions in offering macroeconomic indicators, such as GDP per capita, for which various methods of calculus are known; for instance, in Romania the methodology of obtaining GDP has changed since 2000.
(c) For testing stationarity, the Phillips–Perron test or KPSS test can also be used, with the possibility of revealing different results.

(d) the methodology used in testing co-integration is just one chosen by authors; there are other tests that can be used, as for example Johansen co-integration test.

6. Conclusions

The main purpose of this work was to investigate the causal relationship between energy consumption by fuel and economic growth for two European countries: Romania and Spain and for EU-27. In order to analyze the relation above mentioned, we examined the time-series properties of the data by applying unit root and co-integration tests. The series chosen for the analysis where all non-stationary and in order to make the analysis, they were all transformed in stationary ones using the difference operator. Thus, the series became integrated of different orders, fact that influenced the further testing of co-integration.

For Eu-27 the long-run relationships that could be established were between GDP per capita and energy consumption with source renewables and total petroleum products. Besides these two available also for Romania, another one was also found: between economic growth and energy consumption from source natural gas. For the case of Spain, long-run relationships appeared between GDP per capita and energy consumption with source: petroleum products and natural gas.

Next, the same time series were analyzed for short-run dynamics. The Granger causality test revealed two such relations. The energy consumption with renewable source influences on short-run the GDP per capita in Romania, but not the other way round. Another unidirectional short-run relation appears between Spanish energy consumption with source natural gas and GDP per capita. No bidirectional relationship was found. It seems that the neutrality hypothesis can be also validated for relations tested for EU-27, for two relations in the case of Romania and for one in the case of Spain.

Taking into account the limitations of the study, future research can reveal other important facts about the influence of energy consumption on economic growth and vice versa. For Romania, it is of great importance discovering that renewables are a resource influencing both on short-run and on long-run the GDP per capita. Taking into account that the energy demand is increasing and considering the influence of renewable energy consumption on economic growth for Romania, it is obvious that renewable energy should be exploited increasingly more. On the other hand, both countries should focus on the development of substitute energy for gas, oil and coal, in order to reduce the negative influence of their exhaustible feature.

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